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ABSTRACT

This paper presents an approach to chemistry and nutrition that focuses on food items that people consider delicious. Information is organized according to three categories of food chemicals that provide energy to the human body: (1) fats and oils; (2) carbohydrates; and (3) proteins. Minerals, vitamins, and additives are also discussed along with the food pyramid. A student activity that focuses on chemical analysis of food is also provided. (DDR)

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DELICIOUS CHEMICALS

by

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(Presentation for the American Chemical Society's North-East Regional Meeting at Clarkson University, June 25, 1999)

Picture a mouth-watering meal of your favorite entree: maybe a seafood platter or a prime rib dinner complemented with a drink and a dessert of your choice. These food items are really delicious chemicals. People love chemicals and eat them on a regular basis either at home, special restaurants or at social gatherings and celebrations.

Chemicals are forms of matter that contain one or more elements. They are generally in the form of solids, liquids or gases. One consumes them because they taste good and are a source of energy for the human body. Three categories of food chemicals that provide energy to the human body are fats and oils, carbohydrates and proteins.

Chemicals That We Eat

fats & oils

Food items such as butter, oil, nuts and shortenings are chemicals containing fats and oils. They provide 9 Calories per gram. One Calorie is the energy (amount of heat) required to raise the temperature of one kilogram of water one degree Celsius.

Fats are solid triglycerides and oils are liquid triglycerides. Triglycerides, compounds which store our excess energy as body fat, are esters of triol glycerol with three fatty acids.

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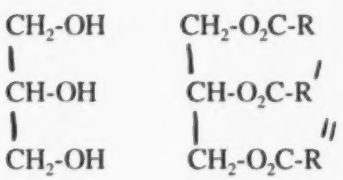
Differences in fats and oils are due to the length or number of carbons in their side chains and the number of carbon-carbon double bonds in their side chains which indicate the degree of unsaturation. In saturated organic compounds carbons are connected to each other by single bonds and in unsaturated compounds the carbon-carbon connections are double or triple bonds. In general one can say that the greater the number of double bonds in the chain, the lower the melting point and the more likely to have a liquid rather than a solid.



glycerol a triglyceride (The Rs represent long, fatty acid side chains).

Catalytic hydrogenation is the addition of hydrogen to the double bonds through the use of a catalyst. Catalytic hydrogenation is important in the production of processed foods such as chocolate candy bars, shortenings and margarine. (Margarine is an emulsified fatty food product used in cooking. It consists of an aqueous phase dispersed in the fat as a continuous phase. It is colored, flavored and fortified with vitamins). Complete hydrogenation of the carbon-carbon double bonds results in a hard and brittle triglyceride. Therefore partially hydrogenated vegetable oils are used to produce semisolid margarines, candies and other consumer products.

The use of partially hydrogenated oils in foods relates to cholesterol, a steroidal alcohol that is associated with atherosclerosis (hardening of the arteries). Cholesterol can be present in our diets, especially those rich in animal fats, and also be made in our livers from saturated fats. Keep in mind that the more hydrogenated the vegetable oils we consume, the more they become

like animal fats. Thus providing raw materials for the liver to produce its own cholesterol.

carbohydrates

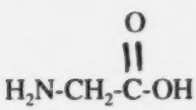
Food items such as potatoes, crackers, breads and pastas are chemicals referred to as carbohydrates. They provide 4 Calories per gram. Carbohydrates are composed of the elements carbon, hydrogen and oxygen. They occur in various shapes and sizes, although the carbon atoms that form them are most always next to one another in unbranched chains. In most cases, the ratio of hydrogen atoms to oxygen atoms in carbohydrate molecules is 2:1.

Carbohydrates include monosaccharides, disaccharides and polysaccharides. The smallest molecular unit of a carbohydrate is a monosaccharide, which literally means one sugar. Glucose ($C_6H_{12}O_6$) found in fruit and honey and known as blood sugar and dextrose, is a monosaccharide. A disaccharide is a molecule formed by combining two monosaccharides. Sucrose, known as table sugar, is a disaccharide formed by combining glucose with the monosaccharide fructose. Polysaccharides, such as cellulose and starch (found in potatoes, corn and grains) are formed by linking hundreds of individual monosaccharides into very long chains.

proteins

Proteins, which provide us with 4 Calories per gram, occur in living cells. They form our hair and nails and along with water are the primary substances of our muscles, organs, blood and skin. Protein molecules consist of long sequences of nitrogen-containing units called amino acids.

The simplest amino acid is glycine.



glycine

Amino acids contain both an acidic carboxyl group (-COOH) and a basic amino group ($-NH_2$). Therefore they have properties of both acids and bases. Essential amino acids are ones that our bodies can't synthesize from other chemicals so we must obtain them from our foods. Nonessential amino acids can be synthesized by our bodies from other chemicals. Foods containing proteins include cheese, peanuts, meat, fish, eggs and milk.

Minerals, Vitamins and Additives

Minerals, vitamins and additives, all food components that don't provide much energy, are needed in very small amounts for life and good health. Minerals are really the less abundant chemical elements of our foods. Major minerals of teeth and bones are calcium (found in milk, cheese and broccoli), magnesium (found in whole-grain cereals, nuts and green vegetables) and phosphorus (found in nearly all foods). Sodium (found in table salt) and potassium (found in meats, dairy products and fruits) have major roles in the regulation of the body's balance of water including the process of sweating. A deficiency of iodine (found in seafood) can lead to goiter, an enlargement of the thyroid gland.

Vitamins are organic compounds formed biochemically in plants, animals and in our own bodies. Vitamins A, D and K are fat-soluble, while the B complex of vitamins and vitamin C are water-soluble. A dietary source of vitamin A (which prevents night blindness) is carrots. Vitamin

D (which prevents rickets, soft and deformed bones) is in fortified milk. Vitamin K (which is needed for blood clotting) is found in plants and vegetables. The B complex of vitamins (which promote good skin and proper metabolism) are found in meats and green leafy vegetables. Vitamin C (which prevents scurvy, a disease marked by spongy gums, and the degeneration of tissues) is especially found in citrus fruits.

Additives to foods are chemicals which make them more appealing, more nutritious, fresh and unspoiled and easier to process. Naturally occurring fragrances and flavorings from plants such as oil of orange and vanilla extract give some of their own tastes and odors to food. Ethyl acetate is an ester found in the plant kingdom. When diluted considerably, its fruity odor and pleasant taste make it valuable in the preparation of synthetic fruit flavorings. Ascorbic acid, known as vitamin C, improves the nutritional value of food and as an antioxidant protects it from oxidation by contact with air.

Chemicals That We Drink

In addition to eating chemicals, one also drinks them. Water makes up most of our body weight and is known as the universal solvent. Soda is a popular drink containing carbonated water, sweetners, coloring and other additives. Alcoholic beverages contain ethanol. Milk is a nutritious drink that includes water, the sugar lactose and more.

Food Chemistry

Food comes from plants and animals. Most food comes from photosynthesis. Green plants rely on photosynthesis in their leaves to form carbohydrates, a source of energy for metabolism and growth. Here carbon dioxide reacts with water in the presence of sunlight and

chlorophyll.

$$6\,CO_2 + 6\,H_2O + 672\text{ kcal} \longrightarrow C_6H_{12}O_6 + 6O_2\uparrow$$

The assortment of chemicals called foods gives us the materials of our bodies and the energy to make them function. Energy, the capacity to do work, can be obtained from chemical reactions. Let's look at it in terms of heat. The kilocalorie, 1000 calories, is represented by Cal and is the amount of heat (or energy) required to raise the temperature of 1000 grams of water 1 degree Celsius. Fat provides us with 9 Cal per gram. Therefore if one has a meal containing 20 grams of fat, the fat provides 180 Cal (energy).

20 grams of fat x 9 Cal per gram of fat = 180 Cal from fat

The energy we take in from food equals the sum of the energy expended and the energy stored as body fat.

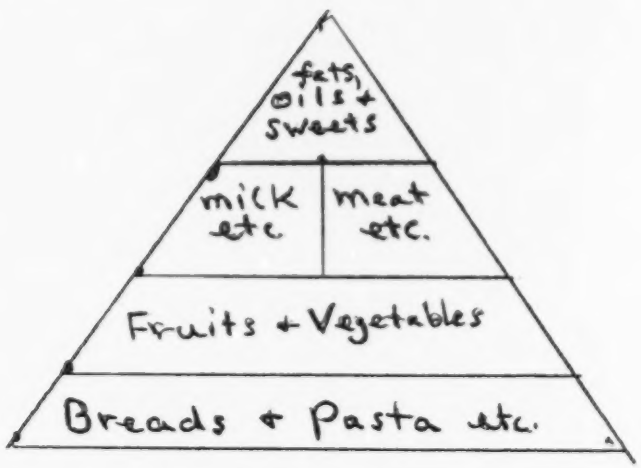
Food must be in a form usable by the human body. During digestion huge molecules of carbohydrates, proteins and fats are broken down into smaller molecules with the help of organic catalysts. These catalysts are enzymes present in the mouth, stomach and digestive tract. Amylase attacks starches and breaks them down to glucose. Pepsin attacks proteins and breaks them down to amino acids, while lipase attacks fats and breaks them down to fatty acids.

Food is oxidized to provide energy. Our primary source of energy is glucose, a monosaccharide known as blood sugar because small amounts of it are present in our blood. It provides fuel for all body cells and is essentially the sole form of energy available to the brain.

Glucose is absorbed from the intestine and stored in the liver and muscles as glycogen. In producing energy, the body oxidizes carbohydrates and fats first. Proteins, important for body building, must be used when there is a deficiency of carbohydrates and fats.

Healthy Bodies

To maintain healthy bodies, one should exercise and eat a balanced diet of chemicals. The types of foods that our bodies need are represented by a food pyramid. The pyramid's foundation includes bread, cereal, rice and the pasta group. Directly above the foundation are the fruit and vegetable groups. Above these groups are the milk, yogurt and cheese group on the left and the meat, poultry, fish, dry beans, eggs and nut group on the right. Food items from all of the pyramid sections mentioned should be eaten daily. The top part of the pyramid contains fats, oils and sweets which should be eaten only occasionally. Total calorie requirements depend on factors such as age, health, size, sex, climate, occupation and activity level.



Food Pyramid

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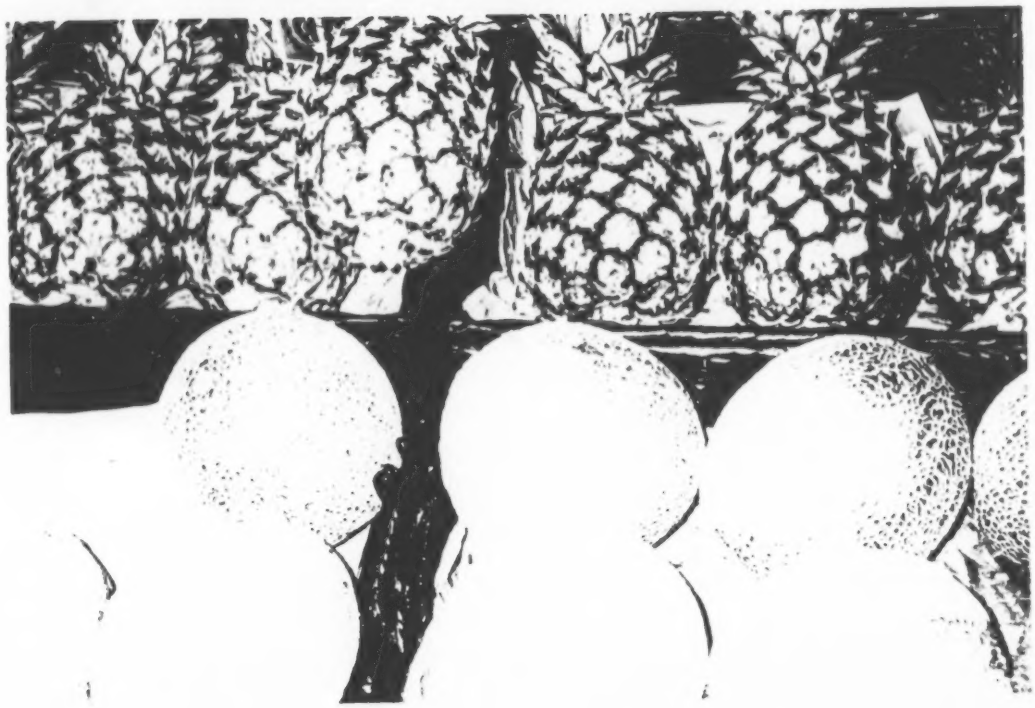
Student Activity

Have each student look at 5 food-item labels, noting the chemicals contained in each item. Then have them complete the chart below. They may refer to a chemical dictionary for assistance.

Chemical Analysis of Food

Food Item	Chemicals Present	Chemical Use
1.	a. b. c.	a. b. c.
2.	a. b. c.	a. b. c.
3.	a. b. c.	a. b. c.
4.	a. b. c.	a. b. c.
5.	a. b. c.	a. b. c.



Fruits contain the sugar fructose ($C_6H_{12}O_6$) and vitamin C

known as ascorbic acid ($C_6H_8O_6$).

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Folic acid ($C_{19}H_{19}N_7O_6$), a member of the Vitamin B Complex, is found in green vegetables and helps prevent anemia.

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